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Price 2s. 6d. Net Monthly

THE METEOROLOGICAL MAGAZINE

July 1963

No. 1092 Vol. 92

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NOTICES

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Printed in England by S. Cockburn & Son Ltd., Ossett, Yorks. and published by

HER MAJESTY'S STATIONERY OFFICE

Price 2s. 6d. **Annual subscription 32s. including postage**

S.O. Code No. 40-43-63-7

METEOROLOGICAL OFFICE M.O. 738

THE METEOROLOGICAL MAGAZINE

Vol. 92, No. 1092, July 1963.

THE INTERNATIONAL METEOROLOGICAL ORGANIZATION AWARD TO DR. R. C. SUTCLIFFE, C.B., O.B.E., F.R.S.

By the DIRECTOR-GENERAL

At its Fifteenth Session in Geneva this year, the Executive Committee of the World Meteorological Organization (WMO) awarded the International Meteorological Organization (IMO) Prize for 1963 to Dr. R. C. Sutcliffe, C.B., O.B.E., F.R.S., Director of Research in the Meteorological Office. Dr. Sutcliffe thus becomes the second British subject to receive this award, the first being Mr. E. Gold, C.B., O.B.E., F.R.S., in 1958.

The IMO Prize was created by the Second Congress of WMO in 1955. The Prize consists of a gold medal, a substantial sum of money and a certificate giving the citation of the award, bearing the signature of the President of WMO and the official seal of the Organization. The award is made annually by the Executive Committee by selection from names proposed by Member countries and it is laid down that "in the selection of the recipient, both scientific eminence and the record of work done in the field of international meteorological organizations should be taken into consideration". The inscription on the medal "Societas Gentium Meteorologica. Pro singulari erga scientiam meteorologicam merito" expresses this thought most concisely.

Dr. Sutcliffe is so well known that it is hardly necessary to go into the details of his long and distinguished career in meteorology. He entered the Meteorological Office in 1927 and his official record covers service both at home and overseas. His best known scientific work is the creation of the development theory of synoptic-scale disturbances, in which the importance of the vertical component of vorticity was brought out for the first time in a clear quantitative fashion. This research helped to lay the foundations of present-day 'numerical forecasting', much of which, to quote one pioneer in this field, is "in the spirit of Sutcliffe's work".

Dr. Sutcliffe became the first Director of Research in the Meteorological Office in 1957, following the Brabazon reorganization. He was elected a Fellow of the Royal Society in the same year. From 1957 to 1961 he was President of the WMO Commission for Aerology and he has also acted as Secretary of the International Association of Meteorology and Atmospheric Physics.

This award has given great pleasure to Dr. Sutcliffe's many friends, both within and without the Office, and is very real evidence of the high regard that his scientific work and his pleasant personality have won all over the world.

551.509.317:551.509.326

A SIMPLE INSTABILITY INDEX FOR USE AS A SYNOPTIC PARAMETER

By C. J. BOYDEN

Introduction.—An instability index is a concise measure of the state of a column of the atmosphere in respect of its temperature structure and sometimes its humidity. Its purpose is to indicate the likelihood of the air becoming unstable when it is subjected to such processes as surface heating and horizontal convergence. The index is not usually related to the weather until energy is supplied in a specified way. Thus air with a high instability index may not produce weather of an unstable character over the sea but thunderstorms are likely to develop in it when it arrives over a heated land surface.

The index of vertical stability most widely known is probably that due to Showalter.[1] Essentially his index is a measure of how near the atmosphere is to releasing potential instability between the levels of 850 mb and 500 mb. Galway[2] introduced a similar index for which a forecast is made of the temperature in the lowest layers. The Showalter index is related basically to the likelihood of instability resulting from convergence whereas the Galway index assesses the consequences of low-level heating, yet both are intended for use in forecasting thunderstorms. It may be that both processes are usually active in thunderstorms or simply that the conditions for potential instability are correlated with those which produce convection.

The index proposed by Rackliff[3] is little different from that of Showalter. The differences are that 900 mb, rather than 850 mb, is the level from which air is assumed to be lifted and the 900 mb wet-bulb potential temperature is used in place of the wet-bulb temperature obtained by lifting the air to the 500 mb level. The limitations of using a potential temperature in this index have been pointed out by Jefferson.[4]

Most indices are designed for use in relation to thunderstorms and similar violent phenomena. They are usually computed from upper air ascents made at night and it is assumed, with fair justification in the circumstances, that the only change in the local atmosphere in the next 12 or 18 hours will arise from surface heating. This is broadly true since heat thunderstorms commonly occur where there is little advection, at least in the lower layers. Nevertheless, about half the summer thunderstorms over the British Isles occur in the vicinity of a front, though often a weak one, and this points to a need for a method of assessing the probability of thunderstorms when the local upper air changes with time are not negligible. It is believed that an instability index is rarely, if ever, used as a synoptic parameter in the sense that instability isopleths are regularly drawn over a complete upper air chart and followed from day to day as are depressions and anticyclones. The nature of the components of an instability index suggests there would be no great difficulty in doing this, but it would take time. The present paper introduces an index which appears to meet all major requirements and can be plotted on a 700 mb chart for all stations over the North Atlantic and Europe within five minutes.

The main requirements in an instability index for synoptic use are the following:

(i) The index must be obtainable quickly.

(ii) The range of values of the index must be large enough for the isopleth pattern to show salient features.

(iii) The index should not be determined to more than a small extent by surface temperature for, if it were, the pattern of isopleths would be seriously influenced by the distribution of land and sea.

(iv) It must be possible to forecast the future pattern from present and past patterns of instability index; since the change is likely to be dominated by advection it is desirable that the layer from which the index is evaluated should not be deep, for then the index would change by shear along the direction of the wind used in estimating the advection.

(v) The index must have a well-defined relationship to the weather in specified circumstances.

The proposed instability index.—In devising an instability index to meet these requirements, the aim was to forecast thunderstorms and heavy rain over south-east England in the months of May to September, this being the period when thunderstorms over England are most frequent. Results were based on the three summers from 1960 to 1962. Reports of thunderstorms and heavy rain or heavy showers were taken from the Beaufort letters describing the weather between 0900 and 2100 GMT each day, the observing stations used being Kew, London (Heathrow) Airport, Gatwick, Thorney Island, Hurn, Felixstowe, Gorleston, Mildenhall and Cardington. This choice of stations was made because they comprise nine of the first ten in the *Daily Weather Report** and give a reasonable network over south-east England. Surface reports were supplemented by sferic (atmospheric) observations over the same hours of the day. The instability index was computed from the Crawley upper air report.

Initially the assumption was made, and appears to be justified, that the development of heavy showers and thunderstorms over land on a summer afternoon depends largely on the mean lapse rate up to 700 mb only, though on most occasions this is related to the lapse rate above that level. If this layer is in a state of neutral static stability for saturated air (that is, with dry-bulb temperatures along a saturation adiabatic) and has a 700 mb temperature of −20°C, the 1000–700 mb thickness is 275 decametres. For a 700 mb temperature of 0°C the thickness is 294 decametres and for +20°C, 313 decametres. (This range of temperature easily covers the extremes ever reached over Crawley in the summer months.) If these temperatures are subtracted from the corresponding thicknesses the resulting figures are 295, 294 and 293, respectively. They are nearly equal because the thickness of the layer in decametres happens to be numerically not very different from its mean temperature in degrees absolute.

In devising the instability index it was assumed that the 1000–700 mb thickness minus the 700 mb temperature (°C) was constant ($\simeq 294$) for neutral stability. Instability was then measured by the extent to which this difference exceeded the constant, and stability by the reverse. In other words, air was

*Meteorologicl Office. *Daily Weather Report, London.*

classed as unstable if the 700 mb temperature was low for the thickness and vice versa. The precise formula adopted for the instability index (I) was

$$I = Z - T - 200,$$

where Z = 1000–700 mb thickness in decametres,
T = 700 mb temperature in °C,

and 200 is subtracted to remove unwanted figures.

It will be noted that I is strictly a measure of the mean stability in the layer below 700 mb. It cannot be used as a measure of the instability in, say, the lowest kilometre or two, where there might be cold and unstable air beneath an inversion; such an atmosphere would have a stable index. This limitation is not of importance since we are not concerned with precipitation forming at low levels, and the index is not intended for assessing the probability of slight or even moderate showers. A similar situation arises when the index is calculated from an ascent made through a frontal surface which is below the 700 mb level. This index is again low and is not representative of the air which is producing most of the frontal rain. Nevertheless, this situation does not occur frequently and the indices affected are easily recognized on a chart.

Local changes of the instability index.—The next consideration is how clear a synoptic pattern the instability index is likely to provide and how successfully the changes in the pattern can be forecast. At Crawley, in the months May to September, the index was found to lie between 88 and 100, about 85 per cent of the values being within the range 91 to 96. These extremes seem to apply quite well over the whole area from Greenland to the Mediterranean, though indices exceeding 100 occurred not infrequently over southern Europe. No difficulty was found in drawing smooth isopleths of instability index when allowance was made for a possible error of unity in any observation. Over the Atlantic a reliable analysis was found to require the drawing of a sequence of charts, as was to be expected.

Analysis of the Crawley indices in the summer of 1962 showed the changes of I between midnight and the following midday to range from -9 to $+5$, though 60 per cent of them lay between -1 and $+1$. The root mean square change was 2.07. Thus the assumption that the midnight index could be used to forecast the likelihood of afternoon thunderstorms (in both frontal and non-frontal situations) would have been acceptable more than half the time but seriously misleading on occasions. Since the instability index is derived from that part of the atmosphere below 700 mb, a forecast of the midday value was made from the midnight chart on the assumption that the index isopleths moved with the 700 mb wind shown on that chart. For the 153 days this method gave no error exceeding 3 and 72 per cent of the errors lay between -1 and $+1$, their root mean square being 1.35. Since I is a whole number which is the difference between two quantities each rounded to the nearest whole number this result is regarded as justification for the advection of the index in this way over 12 hours. Over longer periods a factor such as subsidence would introduce non-advective changes, but there is reason to think that most of the errors would be remote from areas where I was critical in relation to thunderstorms.

In forecasting the index 12 hours ahead one would have expected to find a small but not negligible diurnal variation. If the temperature structure of the air below 900 mb were to change from an isothermal lapse rate at midnight to

a dry adiabatic at midday, there being no change above 900 mb, then the instability index would increase by about 1.5 with no change after convection reached the 700 mb level. An increase of, say, 0.5 might seem a reasonable average for all days in the summer months. It was surprising, therefore, to find that on the average there was a decrease of 0.25 decametres in the 1000–700 mb thickness at Crawley, a decrease of 0.17°C in the 700 mb temperature and a drop of 0.1 in the instability index. When the analysis was confined to non-frontal nights and days the thickness change was +0.4 decametres and I increased by nearly 0.2. These figures suggest that the radiosonde readings are over-compensated for radiation, so a similar computation was made for Trappes, near Paris, including both frontal and non-frontal days. Here the thickness change was +0.12 decametres (against —0.25 at Crawley) and the 700 mb temperature change +0.25°C (against —0.17). Like Crawley, Trappes showed a decrease in I from midnight to midday of 0.1. Whether the diurnal variation of I is as low as this in other countries has not been ascertained, but the instability charts that have been drawn suggest it is small throughout most of Europe.

The instability index in relation to weather.—The next point to be considered is the significance of the instability index in terms of weather. For this purpose the 459 days of May to September, 1960–62, were each classed as non-frontal (N) or frontal (F), according to whether the charts in the *Daily Weather Report* showed south-east England to be in any way affected by a front between 0900 and 2100 GMT. Many of the fronts were, of course, weak, so the F days included a number of situations that were physically as appropriate to the N class. The items tabulated (for the night period as well) were the Crawley 1000–700 mb thickness and 700 mb temperature, the number of stations reporting heavy showers or heavy rain, the number of stations reporting thunderstorms (including, without distinction, lightning seen and thunder heard), the total rainfall from the nine stations and the days with sferics over the area within the 12-hour period.

In the three summers there were altogether 91 days (0900–2100 GMT) on which a thunderstorm was reported by at least one of the nine stations. On all but eight occasions these were confirmed by sferic reports at some time on the same day, the exceptions presumably being due to the occurrence of thunderstorms between the times of sferic observation. In addition there were 43 days when sferics were observed but thunderstorms were not reported from the ground, having evaded the surface observational network. From these figures there seems no doubt that the total number of days with thunderstorms was at least 150, an average of one day in three. The frequency of days of heavy precipitation was much the same as of thunderstorms, though slightly greater when there were fronts and slightly less at other times.

Figure 1 shows, for non-frontal days, the distribution of the instability index and the frequency of days on which thunderstorms or heavy rain occurred somewhere over the area. Figure 2 is a similar histogram for frontal days. The distribution of high-index days is much the same in the two diagrams but the lower indices of 91 and 92 are more frequent on N days, as is to be expected since anticyclonic weather came in this class. On both diagrams there is a marked increase in thunderstorms when I reaches 94 and a maximum in the proportion of thunderstorm days at I = 95 or more. It will be remem-

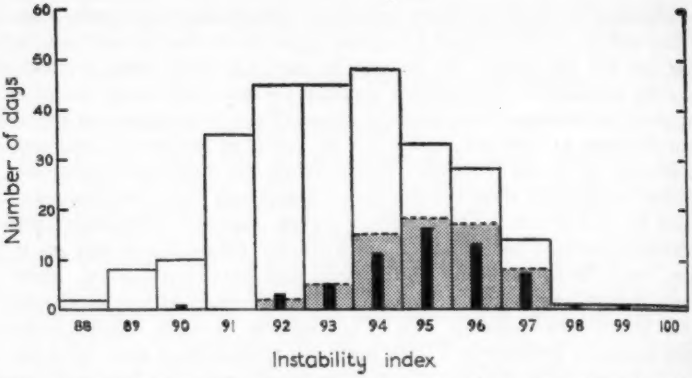

FIGURE 1—FREQUENCY OF NON-FRONTAL DAYS (MAY–SEPTEMBER 1960–62) FOR EACH VALUE OF THE INSTABILITY INDEX

Number of days of thunderstorms —— light shading
Number of days of heavy showers —— heavy shading

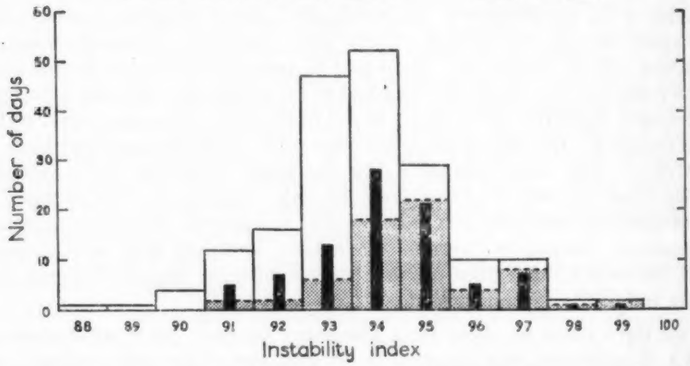

FIGURE 2—FREQUENCY OF FRONTAL DAYS (MAY–SEPTEMBER 1960–62) FOR EACH VALUE OF THE INSTABILITY INDEX

Number of days of thunderstorms —— light shading
Number of days of heavy showers —— heavy shading

bered that $I = 94$ corresponds to mean neutral stability below 700 mb, but the sharpness of the separation is surprising since I involves a computational error which can be as high as unity and, moreover, any variations of I during the 12-hour period were disregarded. The change between indices 93 and 94 is confirmed by Figure 3, which shows, for non-frontal days, the frequencies of various categories of average rainfall from the nine stations. These averages have little absolute significance since on many occasions most of the rain may have fallen at only one or two stations (so Figure 3 should not be regarded as a probability diagram for a particular place). However, the increase in average rainfall exceeding 1.0 mm when I reached 94 is unmistakable. It will also be noted that with an index of 93 or less on a non-frontal day there is an 80 per cent probability that no measurable rain will occur at any of the nine stations. A similar analysis was not made of frontal days because any discontinuity would have been masked by the contributions from slight and moderate rain.

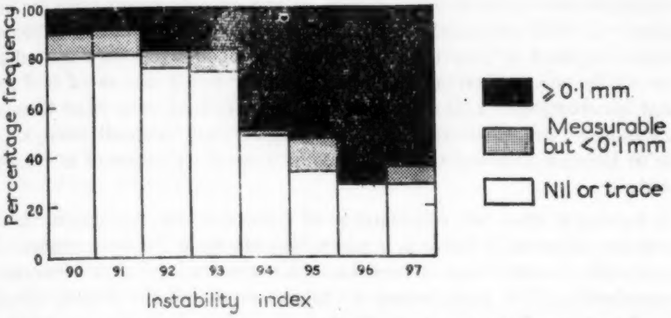

FIGURE 3—VARIATION WITH INSTABILITY INDEX OF THE FREQUENCY OF DIFFERENT AVERAGE RAINFALL TOTALS FOR THE PERIOD 0900–2100 GMT ON NON-FRONTAL DAYS

Table I, in which frontal and non-frontal days are treated separately, includes the information available in Figures 1 and 2 and gives various probabilities according to whether the index is 94 and above or 93 and below.

TABLE I—RELATIONSHIPS BETWEEN THE INSTABILITY INDEX AND THE WEATHER OVER THE AREA*

(*a*) Non-frontal days (0900-2100 GMT)

Instability index at 1200 GMT	88	89	90	91	92	93	94	95	96	97	98	99	100	Total
No. of days	2	8	10	35	45	45	48	33	28	14	1	1	1	271
No. of days with a thunderstorm in the area	—	—	—	—	2	5	15	19	17	9	1	1	—	69
No. of days with a heavy shower in the area	—	—	1	—	3	5	11	16	13	7	1	1	—	58

	Days with instability index ≤ 93 *per cent*	Days with instability index ≥ 94 *per cent*	All days *per cent*
Probability of a day with a thunderstorm in the area	10	49 (60 when $I \geqq 95$)	25
Probability of a thunderstorm at a chosen station	1	14	7
Probability of a heavy shower in the area	6	39	21
Probability of a heavy shower at a chosen station	1	10	5

(*b*) Frontal days (0900-2100 GMT)

Instability index at 1200 GMT	88	89	90	91	92	93	94	95	96	97	98	99	100	Total
No. of days	1	1	4	12	18	47	52	29	10	10	2	2	—	188
No. of days with a thunderstorm in the area	—	—	—	2	2	6	18	22	4	8	1	2	—	65
No. of days with heavy rain or a heavy shower in the area	—	—	—	5	7	13	28	21	5	7	1	1	—	88

	Days with instability index ≤ 93 *per cent*	Days with instability index ≥ 94 *per cent*	All days *per cent*
Probability of a day with a thunderstorm in the area	12	52 (70 when $I \geq 95$)	35
Probability of a thunderstorm at a chosen station	2	9	6
Probability of heavy rain or a heavy shower in the area	30	60	47
Probability of heavy rain or a heavy shower at a chosen station	9	15	12

*The area includes the nine stations: Kew, London (Heathrow) Airport, Gatwick, Thorney Island, Hurn, Felixstowe, Gorleston, Mildenhall and Cardington.

The contrasts are quite striking except in the case of heavy rain in frontal situations. It will be noted that if heavy rain or thunderstorms occur in south-east England at any time in the period 0900–2100 GMT the odds are four or six to one against a particular observer being aware of it from his personal observation. This is relevant to the wording of a local forecast as distinct from an area forecast. In forecasting for, say, a small town, it seems unwise to forecast a thunderstorm unless an instability index of at least 94 is expected.

It is fortunate that the relationship of thunderstorm probability to high or low index, as given in Table I, is practically the same for both classes. Thus if an instability index chart is used to locate areas where thunderstorms are likely to develop it is unnecessary to take account of the frontal situation. The explanation of this is partly that many summer fronts are weak and partly, one presumes, that frontal convergence is roughly equivalent to surface heating as a mechanism for inducing vertical instability.

Humidity in relation to instability.—In devising an instability index it is usual to make allowance for the humidity of the air. In the Showalter index, for example, a variation of one degree in the dew-point at 850 mb is about half as significant as the same variation in the temperature at 500 mb. It was therefore decided to tabulate dew-point and dew-point depression at 700 mb and 850 mb in relation to the index of the present paper, there being a possibility that this would differentiate between non-frontal high-index conditions (94–97) which gave thunderstorms or heavy rain and those which did not. In the rather shallow layer between these two levels the lapse rate of dew-point was found to be almost the same in thundery and non-thundery situations and so, too, was the mean difference in dew-point depression between the two levels. Thus if the vertical humidity structure, taken independently of the instability index, is important in relation to thunderstorms a deeper layer must be studied.

On non-frontal days the mean dew-point depression, both at 850 mb and 700 mb, was 4°C lower when thunderstorms developed with a high index than when they did not. On the other hand, the spread of the values was too great for the dew-point depression to have much forecasting use. It was noted, however, that a thunderstorm occurred only once with a dew-point depression at 850 mb greater than 8°C, a figure which was exceeded on 18 per cent of the high-index non-frontal days. Dryness of the air at low levels may explain the absence of thunderstorms in high-index conditions over parts of Europe, as for example over Spain as shown in Figure 12.

There may be several reasons why humidity, as a predictor additional to the instability index, is so loosely related to the development of thunderstorms. The most likely one seems to be that because of horizontal variations the humidity measured on a single ascent is insufficiently representative of the range of values occurring over the area in a 12-hour period.

The instability index chart.—The full use of a synoptic parameter, as well as its limitations, can be discovered only from experience in applying it; as yet there has not been time to use the instability index on more than a selection of days.

It has been found satisfactory to draw isopleths at intervals of two units and in doing so to allow a tolerance of unity in any observation. The pattern is

usually featureless in some areas, but this is not of practical importance since in such areas the instability index is often uniformly high or low rather than near the critical level of neutral stability. The method of drawing an instability index chart is akin to that of drawing a thickness chart, in that the same use is made of continuity and of the advection of isopleths. For speed and convenience the instability index isopleths can be drawn on the 700 mb chart, the closed centres being marked 'S' (stable) and 'U' (unstable) to avoid confusion with the isobaric highs and lows.

In forecasting thunderstorms and heavy rain the forecaster makes much use of sferic observations. Their limitations are the diurnal variation of thunderstorms over land and the paucity of thunderstorms over the sea. On the other hand, charts of instability index are not materially affected by diurnal variations and do not depend on thunderstorm observations. They are particularly useful over the sea where continuity in the pattern from day to day enables the forecaster to make full use of the sequence of observations from ocean weather ships. Experience is nevertheless required in assessing non-advective changes of index. For example, on general grounds, one would expect cold air moving southwards over the Atlantic to have an increasing index which ultimately reaches a peak of about 95; during the earlier period the instability isopleths would therefore travel at less than the wind speed. Whether this is so can be found only by synoptic experience. Another guide which is subject to verification relates to the central part of a depression. Not only is this a region of fairly high index but the unstable area appears to extend or diminish only by deepening or filling of the depression. Changes due to the temperature of the underlying surface would be expected only if the path were markedly meridional.

Much remains to be learnt about the distribution of thunderstorms in relation to the pattern of the instability index. Sferics were rarely found with an index less than 94 but on the other hand a high index may occur over large parts of Europe without accompanying sferic reports. This was found on a number of occasions over Scandinavia and there it seemed reasonable to regard the cause as inadequate heating in high latitudes. When the expected sferics were missing from areas of southern Europe it seemed that this might be due in part to a limitation of the observing procedure, namely the 'swamping' of distant signals by thunderstorms nearer the observing stations. This is unlikely to be the complete explanation, so a high instability index should be regarded as a necessary condition for thunderstorms but one that needs to be supplemented by information from higher levels in certain situations.

Another aspect that was investigated was whether the 700 mb temperature had any bearing on the probability of thunderstorms over south-east England in non-frontal situations when the index was 94 or higher. With a 700 mb temperature at least 4°C below the monthly mean (this being —5°C in May, —2°C in June, 0°C in July and August and —1°C in September) introduced as an additional condition for thunderstorms the probability rose from 49 to 67 per cent, though to the exclusion of one-third of the thunderstorms that occurred. No such relationship was found on frontal days.

Examples.—Figures 4 to 12 give examples of the application of instability index charts in forecasting thunderstorms between May and September.

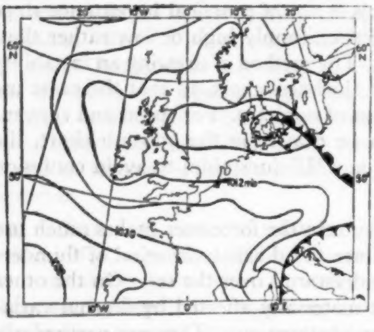

FIGURE 4(*a*)—SURFACE CHART FOR 1200 GMT, 10 MAY 1962

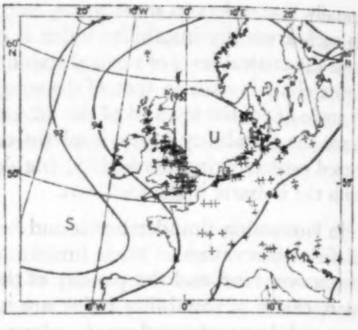

FIGURE 4(*b*)—INSTABILITY INDEX ANALYSIS FOR 1200 GMT, 10 MAY 1962
+ location of sferic reports, 1200–1700 GMT
S 'stable' U 'unstable'

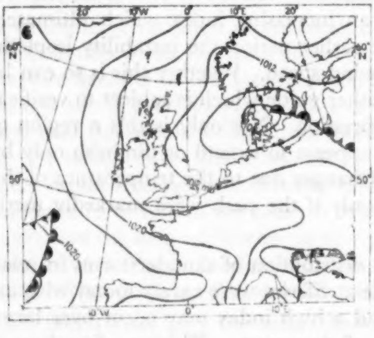

FIGURE 5(*a*)—SURFACE CHART FOR 0001 GMT, 11 MAY 1962

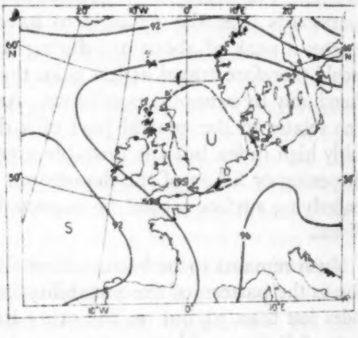

FIGURE 5(*b*)—INSTABILITY INDEX ANALYSIS FOR 0001 GMT, 11 MAY 1962
S 'stable' U 'unstable'

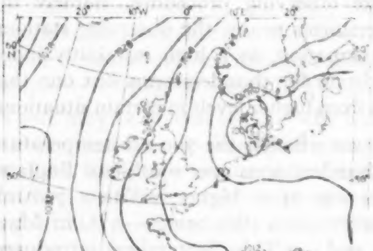

FIGURE 6(*a*)—SURFACE CHART FOR 1200 GMT, 11 MAY 1962

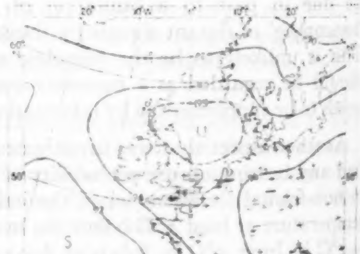

FIGURE 6(*b*)—INSTABILITY INDEX ANALYSIS FOR 1200 GMT, 11 MAY 1962
+ location of sferic reports, 1200–1700 GMT
S 'stable' U 'unstable'

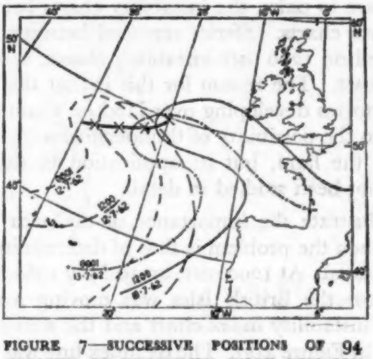

FIGURE 7—SUCCESSIVE POSITIONS OF 94 ISOPLETH OF INSTABILITY INDEX BETWEEN 0001 GMT, 12 JULY AND 1200 GMT, 13 JULY 1962

x–x movement of 700 mb low

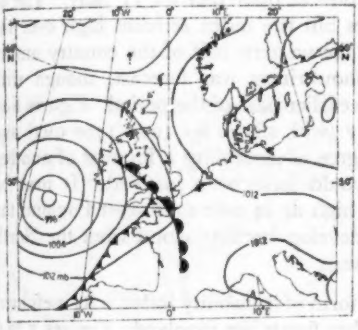

FIGURE 8(a)—SURFACE CHART FOR 0001 GMT, 14 JULY 1962

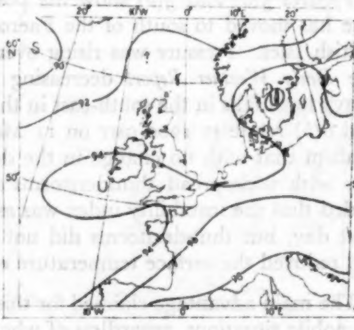

FIGURE 8(b)—INSTABILITY INDEX ANALYSIS FOR 0001 GMT, 14 JULY 1962

S 'stable' U 'unstable'

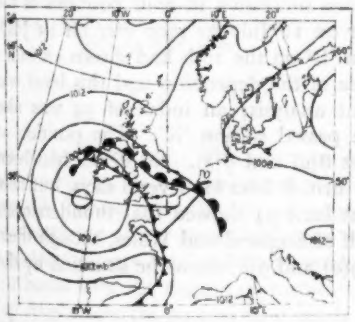

FIGURE 9(a)—SURFACE CHART FOR 1200 GMT, 14 JULY 1962

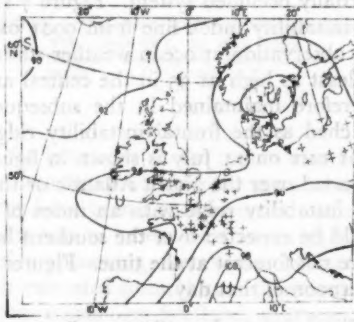

FIGURE 9(b)—INSTABILITY INDEX ANALYSIS FOR 1200 GMT, 14 JULY 1962

+ location of sferic reports, 1200–1700 GMT

S 'stable' U 'unstable'

Most of the charts are in pairs, the instability charts being to the right of the corresponding surface charts. Sferics reported between 1200 and 1700 GMT, inclusive, are marked on 1200 GMT instability charts, but no sferics are shown on charts for 0001 GMT. The reason for this is that the index was devised in relation to thunderstorms developing over land on summer afternoons. It can be used as a guide to the possibility of thunderstorms over the sea and to night thunderstorms over the land, but its application to this smaller number of thunderstorms has not been studied in detail.

Figures 4 to 6 illustrate the importance of the area of high index being clearly delineated when the problem is that of determining whether the risk of thunderstorms has passed. At 1200 GMT, on 10 May 1962, a complex depression lying east–west across the British Isles was moving away to the Continent (Figure 4(*a*)). The instability index chart and the sferics in the period 1200–1700 GMT are shown in Figure 4(*b*). The 94 index line was north of the Faeroes, so it is clear that the southward advection by the light 700 mb winds, as the depression moved away eastwards, would be slow to bring more stable air over England.

Figures 5(*a*) and 5(*b*) show the position at 0001 GMT on 11 May. The 94 line has moved to south of the Faeroes but the index remains high over the British Isles. Pressure was rising over the western half of the country and in the *Daily Weather Report* decreasing showeriness was forecast, though with heavy local falls in the south-east in the earlier part of the period. Figures 6(*a*) and 6(*b*) relate to 1200 GMT on 11 May (with sferics for 1200–1700 GMT) and confirm that with no change in the degree of instability a forecast of another day with widespread thunderstorms would have been justified. It may be added that the instability index was as high as 94 over south-east England the next day, but thunderstorms did not develop because cloud from the North Sea reduced the surface temperature rise.

The main advantage claimed for this form of instability index is its usefulness in mobile situations, regardless of whether fronts are involved. Figures 7 to 9 illustrate its value in assessing the degree of instability likely to be developed on a front when it encounters a warm land surface. Between 9 and 13 July 1962, a warm sector crossed the Atlantic and reached our south-west coasts as a partially occluded system. Figure 7 shows successive 12-hour positions of the 94 instability index line from 0001 GMT on 12 July to 1200 GMT on 13 July. An observation at ocean weather station 'D' on the 10th had shown an index at least as high as 95 in the central area of the depression and this level was therefore maintained in the subsequent analysis; an index of 94 was also reached as the frontal instability ridge passed station 'K'. The position at 0001 GMT on 14 July is shown in figures 8(*a*) and 8(*b*). No sferics had been reported over the North Atlantic or the British Isles for several days, but now the instability ridge with an index of at least 94 showed that thunderstorms could be expected over the southern half of England and Wales, though these were not forecast at the time. Figures 9(*a*) and 9(*b*) show the situation by the afternoon of that day.

Figures 10 and 11 illustrate how unexpected the instability pattern may be in relation to the surface isobars. Figures 10(*a*) and 10(*b*) show an area of high index lying across the north-westerly flow over the British Isles at 1200

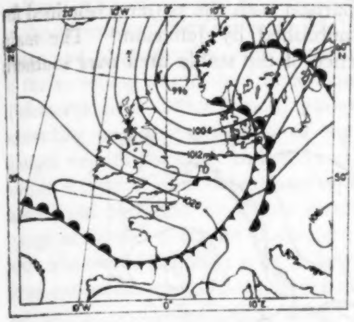

FIGURE 10(*a*)—SURFACE CHART FOR 1200 GMT, 23 MAY 1962

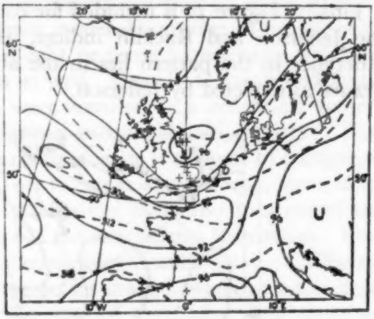

FIGURE 10(*b*)—INSTABILITY INDEX ANALYSIS AND 700 MB CHART FOR 1200 GMT, 23 MAY 1962

+ location of sferic reports, 1200–1700 GMT
S 'stable' U 'unstable'
- - - 700 mb contours in geopotential decameters

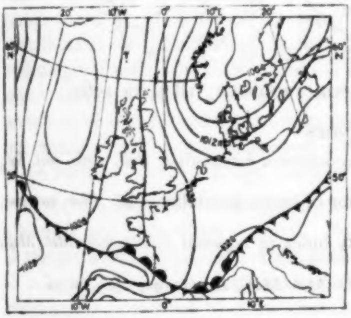

FIGURE 11(*a*)—SURFACE CHART FOR 1200 GMT, 24 MAY 1962

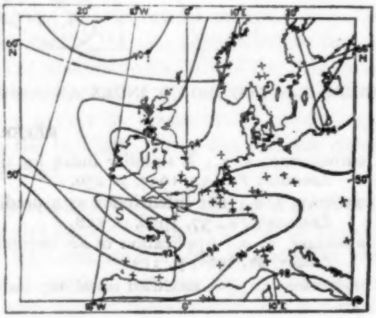

FIGURE 11(*b*)—INSTABILITY INDEX ANALYSIS FOR 1200 GMT, 24 MAY 1962

+ location of sferic reports, 1200–1700 GMT
S 'stable' U 'unstable'

GMT on 23 May 1962. The extension of the instability to the region of ocean weather station 'I' was associated with a depression which filled the previous day. On Figure 10(*b*) the 700 mb contours have been added in order to show the narrowing of the instability ridge which was to be expected as the 94 line moved south over Scotland and remained slow-moving over Wales. Twenty-four hours later the tongue of unstable air extended from Northern Ireland to East Anglia and the air was now much more stable over Scotland, as is seen in Figure 11(*b*). The instability charts suggest that thunderstorms might reasonably have been expected as far north-west as Lancashire but, in fact, they were confined to south-eastern parts of England.

Finally, Figure 12 is included for comparison with the patterns obtained for the Jefferson and Rackliff indices, as published by Jefferson.[4] The main difference in the pattern lies in the absence of the stable area over southern France as depicted by Jefferson.

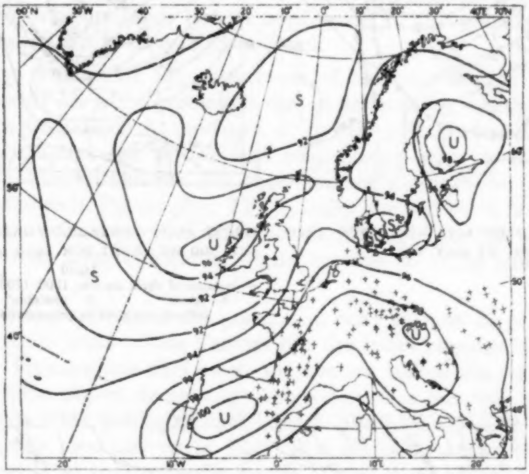

FIGURE 12—INSTABILITY INDEX ANALYSIS FOR 1200 GMT, 18 JUNE 1962

REFERENCES

1. SHOWALTER, A. K.; A stability index for thunderstorm forecasting. *Bull. Amer. met. Soc., Lancaster, Pa.*, **34**, 1953, p. 250.
2. GALWAY, J. G.; The lifted index as a predictor of latent instability. *Bull. Amer. met. Soc., Lancaster, Pa.*, **37**, 1956, p. 528.
3. RACKLIFF, P. G.; Application of an instability index to regional forecasting. *Met. Mag., London*, **91**, 1962, p. 113.
4. JEFFERSON, G. J.; A modified instability index. *Met. Mag., London*, **92**, 1963, p. 92.

551.501.42 (048.1):551.508.77:551.577.2

COMPARISONS OF RAIN-GAUGE MEASUREMENTS

By E. R. C. REYNOLDS, Ph.D.

The work of Dr. Poncelet at the Royal Meteorological Institute, Brussels, should be consulted by all who are concerned about the reliability of the readings from rain-gauges. Lawes[1] has done a great service in translating the most important paper[2] into English, though the translation of some of the statistical terms should be corrected. The preliminary work was presented at the Rome meeting of the International Association of Scientific Hydrology[3] and a later paper in the series was published in 1962.[4] Publication of the methods and results has synchronized with the beginning of the extensive World Meteorological Organization rain-gauge comparisons.

The object of Poncelet's investigations has been the comparison of various rain-gauges from national meteorological services to obtain valid reduction coefficients between them. These studies naturally lead to suggestions to improve the instruments and progressively to eliminate their faults.

Poncelet's method was to group the instruments together on a sheltered site in the grounds of the Institute. He gives a model description of the site using maps and photographs. The environs might be more immediately visualized if the screening angles had been shown as well. French, German and British (Meteorological Office 8-inch) gauges were installed in a systematic pattern, according to the instructions of the various meteorological services. These gauges were duplicated, and this was important since it allowed of comparison within a type as well as between types, or, to put it another way, some allowance could be made for effects resulting from the particular location of each gauge as distinct from the characteristics of the instruments themselves. There were also two of the older type of Belgian rain-gauge (installed rather differently from one another) and three of the newer goblet-shaped Belgian gauges (again not strictly replicating each other). On one of the newer Belgian gauges various wind-shields were tested including the Nipher and Alter shields as well as Poncelet's own designs. Daily records were collected for five years. Climatic information was also collected, and the validity of the approach is emphasized in that, although this data was not always collected at the rain-gauge site, nor in the form most relevant to rain-gauge behaviour, it considerably assisted the interpretation of the data.

Poncelet is careful to point out that he is only assessing rain-gauge efficiency relative to a reference gauge, and he suggests that the absolute accuracy of this gauge could be established by experimental or theoretical means. A further contribution on these lines is in fact promised.[4] He also acknowledges that for hydrological water balance studies it is the absolute accuracy of the rain-gauge which must be known. Until this can be established, he advocates the interpretation of the records from rain-gauge arrays by classification according to the climatic conditions associated with the rainfall. Thus the relative defects of the various types of gauge are determined.

In the comparison of rain-gauges, the relation between the total catches for a lengthy period is often derived. Poncelet begins his examination of the data at this point and concludes that under his conditions it took at least five years to achieve reduction coefficients stable to within one per cent. Subsequent analyses are presented to show that the structure of these coefficients is complex and results from interacting factors which sometimes oppose one another. He states that it is out of the question to apply long-term coefficients to individual small storms.

The method of classifying the records to interpret the behaviour of rain-gauges has been considerably developed by Poncelet. Table I shows the classification he used with the relevant chapter numbers of his work.[2] It is designed to examine the relative efficiency of the various instruments in overcoming splashing into or out of the gauge, infiltration through the joints, evaporation from the funnel and from the collecting vessel, condensation in the funnel, site effects, and losses by the Jevons wind effect. In the classification, rainfall intensity is approximated by the size of the daily catch, the insolation causing evaporation after rainfall by the duration of bright sunshine, and the number of wetting and drying cycles by distinguishing between continuous and intermittent rain. By sub-classifying, the effects of many interactions are suppressed, so that, under otherwise homogeneous conditions, the effects of certain environmental factors become apparent. Some information

TABLE I—SUMMARY OF PONCELET'S CLASSIFICATION OF RAIN-GAUGE RECORDS, INCLUDING CLASSIFICATION BY PREVAILING CLIMATE

§ Section number in Poncelet's paper. [1,8] Figures in brackets give number of records.

UNCLASSIFIED RECORDS (551)

YEAR § 5
1952–53, 1953–54, 1954–55, 1955–56, 1956–57.
(First two years excluded from other analyses)

PRECIPITATION TYPE § 13
Rain
Snow
Size of collection in millimetres § 13
< 10, 10–19.5, ≥ 20

SEASON § 5
Winter, spring, summer, autumn

SIZE OF DAILY RECORD (in millimetres) § 12
<0.5(167), 0.5–0.95(60), 1–1.95(71), 2–4.95(125), 5–9.95(87), 10–19.95(38), > 19.95(3)

MONTHS § 5
Dry months (<40 mm)
Wet months (> 80 mm)

SUNSHINE AFTER RAIN § 6
> 1 hour bright sunshine (20)
½–1 hour bright sunshine (62)
<½ hour bright sunshine (72)
No subsequent sunshine (271)
Character of rain § 7 *and* § 9
Intermittent (107)
Continuous (84)
wind direction § 10 (classified in two ways, (*i*) equal numbers per sector or (*ii*) all available records)

	(*i*)	(*ii*)
N–NE	(5)	(9)
E–SE	(5)	(5)
S–SW	(5)	(45)

wind speed at 28 metres (in kilometres per hour) § 11
<10 (12,) 10–19(13), 20–29(11), > 29(5)

W–NW	(5)	(21)

Size of daily record (in millimetres) § 12
<0.5(27), 0.5–0.95(32), 1–1.95(39), 2–4.95(82),
5–9.95(64), 10–19.95(26), > 19.95(3)
Wind speed at 28 metres (in kilometres per hour), S–SW winds only § 11
<10(24), 10–19(60), 20–29(40), > 29(9)

is lost, of course, since some of the interactions may be of considerable importance. The arbitrary limits of the classes break up a continuous spectrum of variation of the factors, and so a little more information is lost.

Having classified the records, the total catch of each gauge in each class was usually expressed as a ratio of that of one of the new Belgian gauges which was provided with a gauze-covered Nipher shield. Unfortunately this gauge happened to lie on the edge of the array of gauges, but no great objections to its being used as a reference appeared in the figures.

The papers give the merits and demerits of each type of gauge and wind-shield as revealed by this method, care being taken to evaluate the importance of the findings by applying simple statistical tests of significance.

Using Bernard's figures from rain-gauges in the Congo, Poncelet shows how much can be done to analyse records in the absence of data other than that from the compared rain-gauges. He finds that separate recording of day and night rain may be of considerable value. It was encouraging to find that

PLATE I—DR. R. C. SUTCLIFFE, C.B., O.B.E., F.R.S.

See page 197

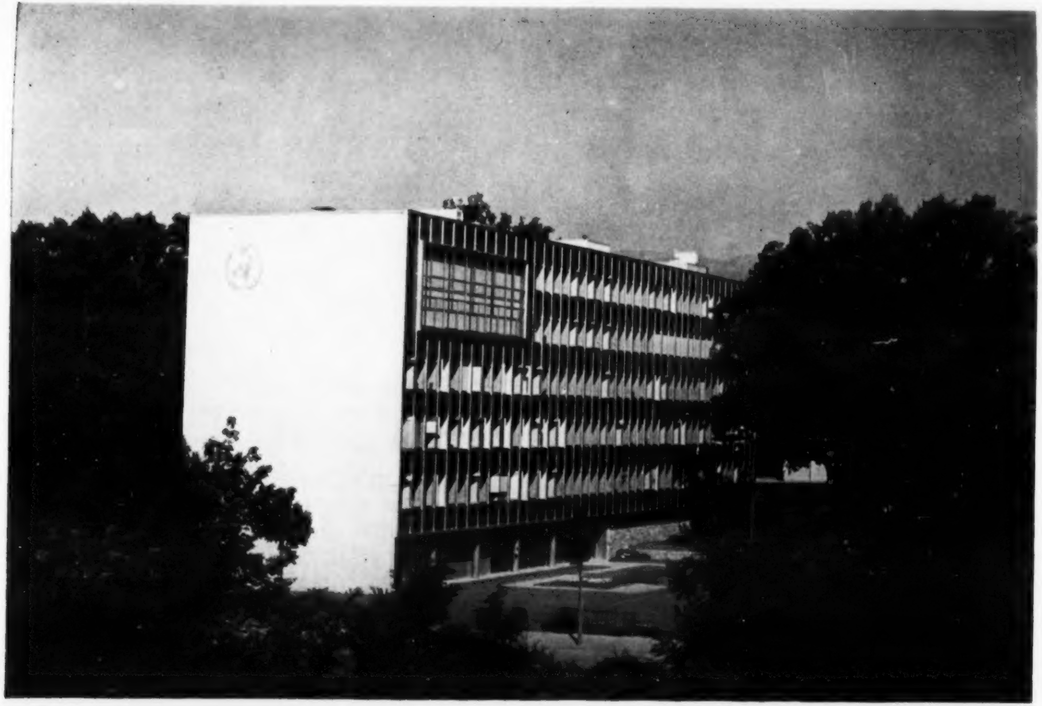

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PLATE II—WORLD METEOROLOGICAL ORGANIZATION HEADQUARTERS IN GENEVA

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PLATE III—AERIAL SYSTEM OF DOPPLER RADAR AT PERSHORE

This was the equipment used in the project described on page 213.

To face p. 213

Reproduced by courtesy of the Ministry of Aviation

PLATE IV—CONTROL EQUIPMENT AND DISPLAY CONSOLES OF THE DOPPLER RADAR AT PERSHORE

This was the equipment used in the project described on page 213. The radar records from a shower, facing page 276 in Volume 91, 1962, of the Meteorological Magazine, were recorded on the camera (top right) shown in this photograph.

reduction coefficients between gauges in the Congo agreed reasonably well with those in Belgium (after excluding, from the latter records, the figures for months when snow fell).

Perhaps the most interesting contribution which Poncelet makes is an attempt to relate the reduction coefficients between rain-gauges from one year to another by using simple climatic parameters. He stipulates that these parameters should be such that they can be obtained from the simplest weather stations. The two which he uses are the number of days with intermittent precipitation (approximated by subtracting the number of days without sunshine from the number of days with measurable precipitation) and the proportion of the total annual precipitation due to snow and sleet. For a given year, the difference of each of these (E_1 and E_2 respectively) from their mean values over five years, when multiplied by empirical coefficients characteristic of the gauges compared (k_1 and k_2 respectively) and summed, gave a reasonable approximation to the differences of the individual annual reduction coefficients, i.e. $k_1 E_1 + k_2 E_2 = \Delta$, where Δ is the deviation of the reduction coefficient from its mean value. Although Poncelet acknowledges that this is an empirical method, he believes that such interpolation formulae may make it possible to circumvent systematic comparisons over long periods in all climates. It will be interesting to see this technique applied in the future. Certainly, considerable weight is given to the possibility that one day there will become available formulae which will relate the absolute accuracy of rain-gauges to measured climatic conditions.

This work by Poncelet has proved most stimulating to the reviewer in connexion with the comparison of rain-gauge behaviour above trees in a wood near Oxford. It is hoped to expand Poncelet's suggestions in the light of this experience in a communication in preparation.

REFERENCES

1. LAWES, E. F.; The behaviour of rain-gauges. East Africa Met. Dept., Nairobi, 1962, (translation of 2. below).
2. PONCELET, L.; Sur le comportement des pluviomètres. Bruxelles, *Inst. mét. Belg.*, Publ. Ser. A, No. 10, 1959.
3. PONCELET, L.; Comparaison de pluviomètres. U.G.G.I. International Association of Scientific Hydrology (Assem. Gén. Rome 1954), Vol. 1, p. 295, Louvain, 1955.
4. PONCELET, L.; Sur le comportement des pluviomètres. Suite 1. Comportement expérimental d'un écran de protection aérodynamique pour pluviomètre. Bruxelles, *Inst. mét. Belg.*, Publ. Ser. A, No. 26, 1962.

551.501.75:551.508.85:551.557

WIND MEASUREMENT BY DOPPLER RADAR

By P. G. F. CATON, M.A., Ph.D.

Summary.—A method is presented for the measurement of upper winds in precipitation conditions by Doppler radar. By combining wind components observed at 10° intervals of azimuth over a wide sector, mean wind speed and direction may be measured at a number of heights simultaneously and the variation of wind both in space and time may be investigated. Observations obtained during the advance of two warm fronts have been analysed. The application of the Doppler technique to the measurement of convergence is examined and preliminary results described.

Introduction.—A recent development in centimetric radar has provided an indication of line of sight velocity of the target through measurement of the Doppler frequency shift in the returned signal. Using a continuous-wave Doppler radar Holmes and Smith[1] have measured a wind velocity of 200 miles/hour in a tornado, but without range information. The meteorological

uses of a pulsed Doppler radar providing simultaneous amplitude, range and velocity information have been examined at the Royal Radar Establishment, Malvern, by Boyenval[2] and Probert-Jones.[3,4] By directing the aerial vertically the fall velocities of precipitation particles may be measured. In warm-front rain where the vertical air motions are relatively small, drop-size distributions may be derived. For convective precipitation Probert-Jones and Harper[5] have deduced estimates of the vertical air motion. If the aerial is directed at moderate angles of elevation, the line of sight velocity includes a component of the horizontal wind and measurements of the velocity along different azimuths may be used to evaluate the wind. This paper describes and assesses the method of wind measurement, presents the results obtained during the advance of two warm fronts and also some data on small-scale space and time wind variations observed in the warm air. A similar use of Doppler radar has been suggested by Lhermitte and Atlas.[6]

Examples of records obtained at Pershore, Worcestershire, have recently been published.[5] Although for these examples the aerial was pointing vertically, the method of display was identical with that used in the wind measurements. Briefly, the information is produced in discrete form and displayed as a matrix on a cathode ray tube, each row corresponding to a range interval along the beam of about 150 metres (500 feet), and each column to a velocity interval of 1 metre/second (2 knots). The echo from the scatterers in each range interval and velocity band is summed and presented on the cathode ray tube as intensity modulation. The display is photographed, each picture having an exposure of 5 seconds.

Evaluation of the wind.—In Figure 1 let the horizontal wind at the point of measurement at height z have speed u and direction θ, let the vertical

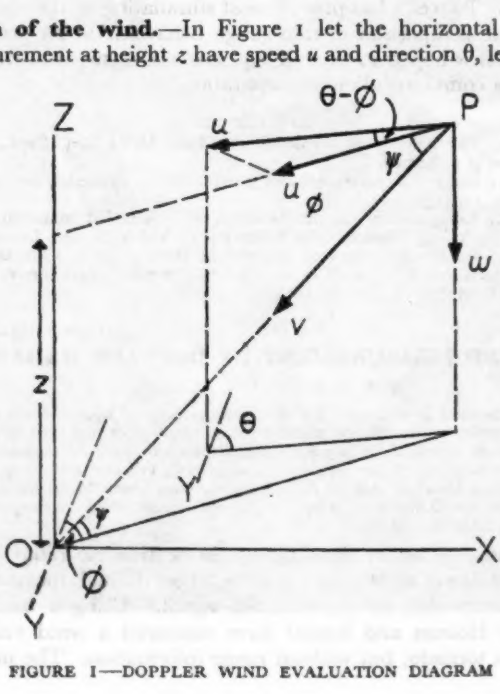

FIGURE 1—DOPPLER WIND EVALUATION DIAGRAM

(downward) velocity of the precipitation particles be w and the radar beam have azimuth and elevation φ and ψ respectively, then, the velocity v, measured towards the radar, is

$$v = u \cos(\theta - \varphi) \cos \psi + w \sin \psi.$$

Hence the component of the wind along the azimuth of the beam, $u\varphi$, is

$$u_\varphi = u \cos(\theta - \varphi) = (v - w \sin \psi) \sec \psi.$$

In order to find the vector wind Probert-Jones[3] combined values of $u\varphi$ for two azimuths θ_1 and θ_2, 20° apart, assuming that the wind was the same at the two observation points. This method of computation is, however, very sensitive to small errors in v which arise from the discrete form of presentation, and it is sensitive also to slight variations in wind between the observing points. Probert-Jones was led to averaging values of u and θ for 20° sectors to give the mean wind over a wider sector.

This mean wind over a wider sector can more easily be deduced through considering that individual values of $u\varphi$ are cosine components of u, the value of u and of the angle $(\theta - \varphi)$ being unknown. Reference to cosine tables shows that, provided the sector examined at 10° intervals of azimuth extends both sides of the wind direction θ, the value of u will be accurately given by the mean of the seven largest values of u_φ (corresponding to angles $(\theta - \varphi) \leq 35°$) subject to an addition of 6.5 per cent. If the mean is taken over the five largest values the addition is 3 per cent. Values of θ may next be deduced from individual values of u_φ, $(\theta = \varphi + \cos^{-1}(u_\varphi/u))$, and a mean taken over those for which $u_\varphi/u \leq 0.85$, $(\theta - \varphi) \geq 32°$, the remaining values being more sensitive to error.

The technique does not require the assumption of complete uniformity in wind between observing points. It is assumed that the speed deduced from observations on azimuths approximately along the wind direction applies also to observations at greater angles to the wind, but small differences in speed would often have little effect on the deduced directions. Further advantages are that aberrant values of θ are immediately apparent and may be checked, and that variations through the sequence may be interpreted as the vector variation of wind within the sector. The method thus reveals both the mean wind over the sector and the internal variation, while possessing the practical merits of simplicity, accuracy and ease of error detection.

Observational procedure.—The normal method of operation was to observe at a beam elevation of 30° ($\sin \psi = 0.5$) and at 10° intervals of azimuth over a sector extending at least 60° each side of the estimated upwind direction. Because of the variation of wind direction with height in frontal conditions the sector frequently extended to 180° or more. The time interval between observations was about 10 seconds, a complete sequence occupying between 3 and 4 minutes. At the beginning and end of each series an observation at 90° elevation was made. These vertically-looking measurements provide a direct record of the precipitation particle fall velocities (w), which in general vary with height.

Recordings were made during the advance of two warm fronts, the first on 8 December 1961, and the second on 28 March 1962. On both dates the above sequence of observations was repeated at intervals of about one hour to define the pattern of wind change through the frontal surface. Additional observations were sometimes made at intervals of 3–5 minutes and occasionally

at two angles of elevation, 23½° and 53° (sin ψ then had values 0.4 and 0.8), in order to explore wind variations in the warm air above the frontal surface.

At 30° elevation the maximum range normally displayed on the cathode ray tube corresponds to a height of about 5½ kilometres (km). However, the height to which winds can be measured is frequently limited by low signal strength to 3–4½ km. At a height of 3 km the points of observation at 10° intervals of azimuth are 0.9 km apart on the arc of a circle of radius 5.2 km. Observations at different heights along one azimuth are not vertically above one another nor in general directly up or downwind. Further, each observation is a mean of radial velocities over an echoing volume determined by the beam width of the aerial, the pulse length of the transmitter and the time constant of the gating circuit; for elevation angle 30° and height 3 km, the volume has a width of 140 m, a length of approximately 300 m and may extend over a height interval of about 270 m.

Wind observations near frontal surfaces.—The variation of the mean wind over the sector of observation during the advance of the front on 28 March 1962 is shown in Table I.

TABLE I—VARIATION OF MEAN WIND DURING THE ADVANCE OF THE FRONT ON 28 MARCH 1962

Height km	Time GMT 1355	1445	1600	1700	1815	1855
			mean wind in degrees/knots			
4.5		262/31				
4.2	264/32	264/30	270/28½	263/34		
3.9	250/32	261/30	272/29½	267/34	284/23½	
3.6	250/32	255/30	272/32	267/33	283/23½	
3.3	254/32	263/30½	275/28	272/30	288/23½	285/23½
3.0	262/33	258/32½	272/27	276/29	285/23	285/27½
2.7	248/32	251/33½	264/31½	277/28	281/21½	284/26½
2.4	227/32	246/34½	253/36½	264/30½	275/22	288/26
2.1	204/30	216/35½	231/38½	246/36	266/24	284/27
1.8	161/32½	197/32	203/40½	218/37	254/29½	268/26½
1.5	162/34	163/32	177/38½	203/40	232/32½	244/29½
1.2	166/35	145/30½	162/38½	185/42	205/36½	211/33½
0.9	162/33	150/31	158/36	166/40	189/36	193/36½
0.6		161/30½	157/34	153/36½	160/33½	169/36½
0.3		171/27½	159/24	145/27	142/26½	142/23½

Observations between the two stepped lines are within the zone of frontal shear.

The boundaries of the frontal zone cannot be precisely defined; the two stepped lines bound observations which appear to be within the zone of strong shear. The shear zone descends at an average rate of 210 m/hr. The speed of advance of the surface front was approximately 50 km/hr, so that the frontal slope may be estimated as 1:240. The vector difference per 300 m height change within the zone of strong shear ranges from 3 to 23 knots with a mean of 13.3 knots. This mean shear, if entirely of thermal origin, corresponds to a local temperature gradient of 7.5°C/100 km. By comparison the mean vector wind difference per 300 m height change in the warm air well above the frontal surface is 2.5 knots.

The mean winds observed during the second frontal situation are shown in Table II. In this case the rate of descent of the shear zone was only about 70 m/hr, associated with a slow rate of advance of the surface front. The two final columns illustrate the short-period fluctuations in mean wind which sometimes occur.

TABLE II—VARIATION OF MEAN WIND DURING THE FRONTAL SITUATION ON 8 DECEMBER 1961

Height km	Time GMT 1255	1355	1450	1540	1630	1730	1737
	Mean wind in degrees/knots						
3.3				232/26		218/30½	229/29
3.0		246/27½		231/27		218/31	222/28
2.7		243/26½		228/27½		216/28	222/30
2.4		241/25	235/23½	222/26		216/27½	226/31½
2.1		248/22½	238/23½	218/23½	228/25½	211/27	219/30½
1.8		240/17	234/23	219/21½	222/27½	208/25½	219/29½
1.5	245/–	233/20	232/25	225/22	226/28	219/26½	219/25
1.2	251/17	227/22	218/26	228/25½	229/29½	225/29½	220/26
0.9	201/32	207/23½	215/25	227/25½	228/27	224/28	225/29½
0.6	177/39	184/32	195/30½	196/26½	201/24½	211/33	211/33½
0.3	166/27½	162/30	167/29	166/32	169/27	171/27½	176/29½

Observations between the two stepped lines are within the zone of frontal shear.

Accuracy of wind evaluation.—An individual value of v (or w) derives from the observation of echo in one or more velocity channels centred 1 m/sec apart. The relative strength of the signal between channels permits estimation of the mean v in units of 0.25 m/sec. The spread of recorded velocities is due mainly to the variations of wind within the echoing volume and to the range in precipitation fall velocities. Above the 0°C level in warm-front rain the particle fall velocities are very uniform at about 1–2 m/sec. Below the melting level the fall velocity of the raindrops has a wider span, from 2 to sometimes 9 m/sec, which results in greater error in estimation of mean values. From consideration of the several factors and from the values recorded by two observers working on the same data, it is estimated that the standard error of measurement of the derived values of u_φ is 0.25 m/sec at heights above the 0°C isotherm and 0.75 m/sec below.

Above the 0°C level the standard error in mean values of u should not exceed 0.1 m/sec from measurement causes alone, since each mean is derived from a set of seven values of u_φ. However, the actual variations within each set exceed expectation, undoubtedly because of small but real variations of u between observing points. From the general run of values it is deduced that the total standard error in mean values of u is about 0.2 m/sec (0.4 knots) and, accordingly, values have been recorded to this accuracy. Assuming a wind speed of 30 knots (the approximate average for the days of measurement) the standard error of measurement of u_φ corresponds to a standard error in θ of 1.5°. However, the observed average standard deviation in θ, excluding abnormal values (see a later section), is 2.1°. The expected standard error in a mean of eight values of θ is therefore 0.8°, equivalent to a vector of 0.4 knots.

The total standard error of the vector mean winds in Tables I and II is thus estimated as $\sqrt{((0.4)^2 + (0.4)^2)} \simeq 0.6$ knots. The variations between values in those Tables are therefore considered to be largely real.

Wind variability.—The Doppler radar provides a possible means of investigating space and time variations in wind. It must be stressed that the short analysis which follows refers to two dates only and to levels above warm-front surfaces ($2\frac{1}{2}$–$4\frac{1}{2}$ km above ground). A principal aim is to illustrate the types of variation which may be studied.

(i) *Wind variations within an echoing volume.*—Even if the wind were uniform in space a spread of velocities would occur during a single observation of v due to measurement over a finite beam and to variations in precipitation fall velocity. However, these causes account for only a small proportion of the velocity spread normally observed at any one range. The major cause of velocity spread is wind variations within the echoing volume and these are found to have standard deviation 1.3 m/sec (2.5 knots). Part of this is due to turbulent fluctuations, and part to changes in the horizontal wind across the vertical extent of the echoing volume.

Subsequently in this section the term 'wind' will refer to the average value over an individual echoing volume and 'mean wind' to the mean over the sector of observation of wind values centred at one height.

(ii) *Wind variations between echoing volumes at one height.*—As indicated in the previous section the observed standard deviation of derived angles θ (2.1°, excluding abnormal values, see paragraphs below) exceeds that expected (1.5°) solely due to errors of measurement of the components u_φ. The excess indicates the existence of real variations either of u or θ or both between echoing volumes. The standard deviation of these variations was deduced to be 1.5°, equivalent to a vector of 0.40 m/sec (0.8 knots) for a wind speed of 30 knots. This value for the wind variability, derived from observations along azimuths broadly at right angles to the wind, compares closely with that of 0.38 m/sec (0.7 knots) deduced from the run of values of u_φ observed on azimuths close to the wind direction.

A typical series of observations of $u_\varphi \cos \psi$ and derived values of θ is shown below:

Azimuth (deg)	130	140	150	160	170	180	190	200	210	220	230	240
$u_\varphi \cos \psi$ (m/sec)	$-8\frac{1}{2}$	-6	-3	0	$2\frac{1}{4}$	5	7	8	10	$11\frac{1}{2}$	$12\frac{1}{2}$	$13\frac{1}{2}$
θ (deg)	257	255	252	250	251	249	251	256	255	256	–	–
Azimuth (deg)	250	260	270	280	290	300	310	320	330	340	350	
$u_\varphi \cos \psi$ (m/sec)	$13\frac{3}{4}$	$14\frac{1}{2}$	14	$12\frac{3}{4}$	12	$10\frac{3}{4}$	$8\frac{1}{2}$	$6\frac{1}{2}$	$3\frac{1}{2}$	$1\frac{1}{2}$	$-\frac{1}{2}$	
θ (deg)	–	–	–	–	–	259	257	257	254	256	258	

It will be seen that while the values of θ for azimuths 130–140°, 200–220° and 300–350° are grouped about a mean of 256° with standard deviation 1.4°, those for azimuths 150–190° have a mean of $250\frac{1}{2}$°. This behaviour by five adjacent values covering a distance span of about 5 km is considered to indicate a real difference of wind from the remainder of the sector and will be termed an abnormality. In general it is not possible to be sure whether it is the wind direction or speed or both which vary, but in this case the abnormal observations are along azimuths nearly at right angles to the wind and give information on direction rather than speed.

In a sample of 30 sectors at different times and heights ($2\frac{1}{2}$–$4\frac{1}{2}$ km) 9 showed entirely random variations in the θ values. The remaining 21 showed 23 abnormalities in θ values extending over sub-sectors of 20° or more. Frequently

an abnormality at one height occurred in modified form 300 m above or below. The sizes of the sectors involved ranged from 20° to 90° azimuth with a mean of 42°, corresponding to a linear distance of 3.8 km at height 3 km. The abnormalities in wind direction varied from 3° to 14° with a mean of 6.4°, equivalent to a vector change of 3.4 knots. Overall, the abnormalities covered 22 per cent of the θ values surveyed. However, this percentage was higher for the azimuth sector 140°–230° (32 per cent) than for the sector 310°–360° (14 per cent), and it is possibly significant that the southerly sector was directly downwind (10 miles) of the Malvern Hills on the day concerned.

Observations were occasionally made at two beam elevations, $23\frac{1}{2}°$ and 53° (sines 0.4 and 0.8), to investigate wind variations along radial axes. At a height of 3 km the pair of observations at one azimuth are 4.6 km apart. The root mean square vector difference in wind between observations at one azimuth was close to that for observations along circular arcs. This suggests that results derived from the more numerous circular arc observations are representative of both axes. The over-all picture of wind variations in a horizontal plane on the dates concerned is therefore of random fluctuations of about 1 knot and systematic deviations of 2–5 knots over regions a few kilometres across; the latter are perhaps particularly associated with hills.

(iii) *Wind variations over short time intervals.*—On both dates series of observations were made in quick succession to investigate wind variations over short time intervals. For one period, 1819–1837 GMT, 28 March, 1962, during which wind variations above the frontal zone appeared to be essentially random in character, the root mean square (r.m.s.) change in wind component (ue) at an individual height and azimuth is shown in the left portion of Table III. The root mean square changes in mean wind direction and speed at an individual height are given in the right section of the same Table.

TABLE III—ROOT MEAN SQUARE CHANGES IN INDIVIDUAL WIND COMPONENTS AND IN MEAN WIND DIRECTION AND SPEED FOR VARIOUS TIME INTERVALS FROM 1819 TO 1837 GMT, 28 MARCH 1962

Time interval *minutes*	No. of pairs of 'components'	R.m.s. change of 'component' *knots*	No. of pairs of mean wind	R.m.s. change in direction *degrees*	R.m.s. change in speed *knots*	R.m.s. vector change *knots*
4	88	1.35	5	2.2	0.75	1.15
7	175	1.35	12	2.2	0.7	1.1
11–14	162	1.5	11	2.4	0.8	1.25
18	76	1.35	5	2.3	0.9	1.3
Values arising solely from errors of evaluation		0.35		1.2	0.7	0.85

Significant changes occurred both in individual wind components and in mean wind direction. During a second period (8 December 1961) much larger fluctuations were observed both in individual components and in mean wind, e.g. root mean square vector changes in mean wind of 2.8 knots over 7–9 minute intervals, 3.9 knots over 18–25 minutes and 5.1 knots over 37–40 minutes. The latter values compare closely with those derived by Durst[7] from observations of smoke puffs at comparable heights.

Measurement of convergence.—With the accuracy of measurement of velocity given by the Doppler radar it seems possible that a measurement of convergence can be obtained by summing the radial components of wind

observed throughout a 360° rotation. It is possible that a single summation will be substantially affected by purely local air motions since the area examined (e.g. 85 km² at height 3 km) is rather small for this type of measurement, but repetition of the observations may indicate systematic trends associated with larger-scale phenomena. If wind component observations are made at 10° intervals of azimuth

$$2\pi r \frac{\Sigma u_{\varphi}}{36} = \pi r^2 D,$$

where D is the convergence (+*ve*) or divergence (—*ve*) and r is the radius of the circle of observation at height z. It is assumed that the wind component varies linearly between 10° points and that changes are negligible within the time required for a 360° rotation.

An initial test, using wind observations corresponding to the first column of Table I, gave values of convergence as shown in Table IV. Computation was not possible outside the height range indicated, as echo was not continuous throughout the 360° rotation.

TABLE IV—VALUES OF CONVERGENCE AND VERTICAL VELOCITY AT 1355 GMT, 28 MARCH 1962

Height *km*	Convergence $\frac{sec^{-1}}{\times 10^{-5}}$	Increment of vertical velocity in 300m layer *cm/sec*	Vertical velocity at top of layer *cm/sec*
3.3	7.8	2.4	35.0
3.0	−1.2	−0.4	32.6
2.7	15.1	4.5	33.0
2.4	3.9	1.2	28.5
2.1	9.2	2.7	27.3
1.8	24.2	7.3	24.6
1.5	43.1	12.9	17.3
1.2	14.7	4.4	4.4

Value of vertical velocity in last column assumed zero at 1.05 km.

Three of the four largest convergence values occur immediately below the zone of strong wind shear. The increment in vertical velocity within layers 300 m deep is calculated and also the total velocity assuming, for convenience, that the velocity at 1.05 km is zero. This assumption is of course unlikely to be valid. The maximum vertical velocity of 35 cm/sec seems essentially reasonable. However, too much reliance should not be attached to the absolute value which may, in this instance, have been considerably affected by small inaccuracies in the setting of the velocity zero and the measurement of w (the fall velocity of the precipitation particles). Errors from these causes are systematic in assessments of convergence and precautions to minimize them must be taken with great care. The method shows considerable promise and further measurements are planned.

Discussion.—The Doppler radar provides a possible means of measuring in precipitation conditions both the mean wind at different heights and times, and the variations of wind over horizontal distances of a few kilometres and over time intervals of a few minutes. Each individual observation by Doppler radar is of a component of the wind averaged over an echoing volume which very approximately is a 200 m cube. Above the 0°C level in frontal precipitation the estimated standard error purely of measurement is about 0.25 m/sec. Through sampling several volumes at each height a mean wind may be derived, the limit of accuracy being set by the inherent variability of the air motion.

By comparison a wind measurement by conventional radar is an average over a height interval of about 400 m along the path of a single balloon and the standard error of measurement is about 1 m/sec. Further interesting features of a Doppler technique are that individual component measurements are effectively instantaneous in time and that, if wind changes are being studied, frequent measurements are possible at precisely repeatable heights. It should be stressed, however, that a Doppler radar cannot measure wind speed and direction with uniform accuracy throughout the sector of observation; measurements near the wind direction accurately indicate the speed but give less reliable information of direction, whilst measurements at right angles to the wind accurately indicate direction.

The limitations of the Doppler technique are the requirement for precipitation over a substantial sector around the radar and the moderate height to which observations may normally be made (with this particular radar 3–5 km in light or moderate precipitation). The unambiguous range of velocity display (a function of radar wavelength and pulse-repetition frequency) is 19 m/sec (37 knots), although it is possible to investigate components of one sign up to twice the above value. However, in strong wind situations it would be more convenient to work at a beam elevation of 60°. Wind measurement would be slightly less accurate but observations to a greater height might be possible since ranges of detection are shortened. By contrast if the winds are light at all levels, use may be made of a facility which converts the velocity channels to 0.5 m/sec intervals.

The application of the Doppler wind technique to the measurement of convergence appears most promising and may permit estimation of the vertical motion associated with fronts, and a study of the variations in space and time which perhaps are associated with the rainfall variations frequently observed. A further possibility is the investigation of vertical motions associated with gravity waves induced by hills.

In conclusion the distinctive features of Doppler wind measurement may be summarized as:

(i) requires steady precipitation over the sector of observation,

(ii) when looking cross-wind an instantaneous measurement of wind direction may be obtained,

(iii) wind speed or direction at a fixed point may be measured at short time intervals (every 5 seconds if necessary) over a long period during which the standard of measurement is unchanged. This compares favourably with smoke puffs, which can be followed for only a few minutes and only in clear skies, and with metal foil, which spreads rapidly in the vertical,

(iv) mean wind direction and speed over a sector of observation may be measured at repeatable heights every few minutes, and may be used, for example, to reveal the detailed pattern of wind change through a frontal zone,

(v) being a radial component, is immediately usable in an assessment of convergence.

Acknowledgement.—The author wishes to thank the Chief Scientist, Ministry of Aviation and the Director, Royal Radar Establishment for their approval of meteorological use of the Doppler radar equipment, and for providing generous facilities.

REFERENCES

1. HOLMES, D. W. and SMITH, R. L.; Doppler radar for weather investigations. Proc. 7th Weather Radar Conf., Miami, Fla., 1958, p. F-29.
2. BOYENVAL, E. H.; Echoes from precipitation using pulsed Doppler radar. Proc. 8th Weather Radar Conf., San Francisco, Cal., 1960, p. 57.
3. PROBERT-JONES, J. R.; The analysis of Doppler radar echoes from precipitation. Proc. 8th Weather Radar Conf., San Francisco, Cal., 1960, p. 347.
4. PROBERT-JONES, J. R.; Meteorological use of pulsed Doppler radar. *Nature, London,* **186,** 1960, p. 271.
5. PROBERT-JONES, J. R. and HARPER, W. G.; Vertical air motion in showers as revealed by Doppler radar. *Met. Mag., London,* **91,** 1962, p. 273.
6. LHERMITTE, R. M. and ATLAS, D.; Precipitation motion by pulse Doppler radar. Proc. 9th Weather Radar Conf., Kansas City, Mo., 1961, p. 218.
7. DURST, C. S.; Variation of wind with time and distance. *Geophys. Mem., London.,* **12,** No. 93, 1954.

FOURTH CONGRESS OF THE WORLD METEOROLOGICAL ORGANIZATION

By C. W. G. DAKING, B.Sc.

The Fourth Congress of the World Meteorological Organization (WMO) was held in the Palais des Nations, Geneva from 1–27 April 1963. It was attended by representatives of 102 Member States or Territories, by observers from 3 non-member countries, and by representatives of 25 other international organizations. The Congress was presided over by M. André Viaut, Director of the French Meteorological Service, acting in this capacity for the second time. The delegation of the United Kingdom was led by Sir Graham Sutton, Director-General of the Meteorological Office, who was assisted by Mr. C. W. G. Daking, Mr. B. M. Day (Air Ministry F.1), Instructor Captain J. A. Burnett R.N., Director of the Naval Weather Service, Admiralty, and Mr. D. H. Anderson of the Foreign Office. Miss J. M. Prior acted as secretary to the delegation.

As is customary, the large agenda, consisting of over 50 items, was dealt with by means of three working committees although in the event, it would have speeded up the work to have had an additional committee to deal with Technical Co-operation matters, especially as these took up a great deal of the time of the Administrative and Finance Committee.

For the purposes of this article, attention has been focused on the major items dealt with by each committee.

Legal and general questions.—In accordance with a decision made at Third Congress, the Executive Committee (EC) reviewed the WMO Convention during the period 1960–62 and submitted its proposals for revisions to Fourth Congress. Much of the work involved had been done by a Working Group of the EC of which the Director-General was a member. In addition to the amendments proposed by the Executive Committee, several members submitted amendments in accordance with Article 28(*a*) of the Convention. Much of the time of the Legal and General Committee was taken up on this

item, discussion being lengthy because of the diverse views adopted towards the changes proposed and the consequent difficulties of obtaining principles and texts which were acceptable to a substantial majority of the Committee.

Two amendments which had an easy passage concerned Article 13(*c*)—composition of the Executive Committee. It had been expected that a move towards a larger EC would be made and although several delegations pointed out that a larger Committee might be somewhat less efficient and effective, there was no real opposition to increasing the number of members from 18 to 21. Similarly, the proposal by Australia that no Region should have less than 2 members found general acceptance. The Resolution putting forward these two changes to Article 13(*c*) was passed by Congress with 81 votes in favour and no votes against.

The document submitted to Congress concerning other amendments to the Convention ran to 24 pages of text and to 11 pages in the Appendix containing 19 proposed amendments. Of these, 5 failed to receive 71 votes in favour, the number necessary for their adoption by Congress and subsequent embodiment in the Convention.

Fortunately, the Articles of the WMO Convention are self-contained and the adoption of new texts for 14 Articles will not cause confusion. However, in view of the legal difficulties encountered during the discussion in Committee, it was decided to establish a Working Group of Congress to make a further study on the form and wording of the Convention. This Group is to report to the President of WMO 18 months before Fifth Congress so that its recommendations may be examined by Members in time for them to comment within the 6 months time limit provided for in Article 28(*a*) of the Convention. The United Kingdom was invited to designate an expert to serve on the Working Group and it is probable that the Foreign Office will make the nomination.

Substantial amendments were made to the General Regulations of the Organization. Proposals for these emanated from the Executive Committee and from Members. Some concerned procedural matters, such as voting by correspondence. The regulations concerning the convening of and agenda for sessions of constituent bodies were completely rewritten. Far reaching changes were made in the languages section, since it was decided that in addition to English and French, Russian and Spanish shall be working languages of the WMO. This means that interpretation and documentation in four languages will be required at sessions of Congress, the Executive Committee, Technical Commissions and some of the Regional Associations. The financial and other implications are considerable, but it must be conceded that the use of four languages (when required) will contribute to a better understanding of written texts and a greater clarity in oral presentations. The burden on countries which 'host' sessions, however, will be very greatly intensified.

Somewhat contrary to expectations Congress was not confronted with a serious problem with regard to invitations to constituent bodies to meet in various countries during the Fourth Financial Period. Several Commissions had received more than one invitation. Only one, the Commission for Maritime Meteorology was without an invitation and budgetary provision was made for that Commission to meet in Geneva at the Headquarters of the Organization if necessary.

Technical questions.—By far the most important matter dealt with on the technical side was the question of Meteorological Satellites and the associated subjects of World Weather Watch and Network Development.

Discussion centred around the First Report of WMO on the Advancement of Atmospheric Sciences and their Application in the light of developments in Outer Space, and the reports of the EC Working Groups on Research Aspects and Artificial Satellites. The concept of a World Weather Watch was generally commended as an exciting development ultimately leading to a World Weather Service. It would be composed of the national and international efforts of Meteorological Services in a co-ordinated plan for the making of observations, their communication to National, Regional and World Centres and the processing of analyses and prognoses and their distribution to those Services which desire them. But an accelerated effort to acquire additional conventional data is necessary in order to achieve maximum benefit from data from meteorological satellites and for this reason considerable attention is to be paid to network development during the Fourth Financial Period. Congress confirmed the approval in principle given by the Executive Committee to the development plan for world-wide networks established by the EC Working Group on Networks. While recognizing that the primary responsibility in establishing and operating observing stations rests with Members, Congress agreed that the WMO should assist Members in completing the observation programmes at existing island and continental stations listed in the plan in cases where such assistance is requested and the need for it is clearly demonstrated. In addition, Congress agreed that the Organization should prepare a detailed plan to enable the remainder of the plan i.e. new island stations, ocean weather stations, automatic weather stations and so on to be completed by 1974. Priority is to be given to areas between 50°S and 65°S.

In view of the need for increasing attention to be given to scientific and technological developments Congress established an Advisory Committee to the Executive Committee whose main tasks will be to advise on all the scientific aspects of the objectives given in United Nations General Assembly Resolutions on Outer Space and on major operational problems relating to these Resolutions. In addition, the Committee will advise on training and education at all levels and on the co-ordination of the scientific activities of the constituent bodies of WMO especially those relating to metetorological satellites. The Committee will be a WMO body and will maintain close contact with other organizations active in the science of meteorology and related disciplines; for this reason it will contain members who can present the views of the International Council of Scientific Unions (ICSU). Reports of the Advisory Committee will be made available, as appropriate, to Members and to Technical Commissions.

Congress decided that before a complete international programme for improving the world weather observational and forecast system (World Weather Watch) could be adopted, a comprehensive study should be carried out with special reference to:

(i) an analysis of national requirements to be placed on the system and the advances in technology that should be utilized to meet these requirements, and

(ii) an overall plan for observational methods and networks, communications systems, processing centres, data distribution and other essential

functions of such a system. It requested the Executive Committee to arrange for the study to be completed by mid-1965.

So that the work outlined above could proceed and be properly co-ordinated it was decided to establish a Planning Unit in the Secretariat with the following duties:

(*a*) To assist in the development of the detailed global plan for the World Weather Watch.

(*b*) To provide support to the WMO Advisory Committee and other WMO bodies concerned with outer space questions.

(*c*) To assist in the preparation of reports and supply of information as required by the United Nations (UN) and its agencies.

(*d*) To review continuously the possibilities of obtaining financial assistance for implementation of global plans.

With regard to the structure and terms of reference of Technical Commissions the only aspect that gave rise to discussion and indeed dissension was the terms of reference of the Commission for Hydrometeorology. Several countries were violently opposed to the acceptance by WMO of any aspect of the subject which impinged on pure hydrology. Others pointed out that it was unsatisfactory for there to be divided responsibility for hydrology, that UN had looked to WMO to co-ordinate international aspects and that WMO should not shirk the task.

Terms of reference were finally agreed in Plenary after some two hours of discussion. The main changes from those proposed by the Technical Committee were the substitution of 'hydrometeorology' for 'hydrology' wherever this was possible so the that emphasis was transferred from hydrology to hydrometeorology.

Lengthy discussion also took place regarding the name of the Commission. A large majority disliked the awkward title Hydrological Meteorology and finally Hydrometeorology was adopted.

It was agreed that there was a need for WMO to take a more active part in the planning of and participation in international oceanographic projects particularly to ensure co-ordination of meteorological programmes on fixed oceanographic stations and the compliance of such programmes with WMO procedures. The Intergovernmental Oceanographic Commission (IOC) of UNESCO had already expressed a wish for close collaboration with WMO.

It was necessary, therefore, for WMO to take part in all IOC meetings; later a joint WMO/IOC working group might have to be set up. It was also agreed that IOC should be represented at meetings of relevant WMO bodies. A Resolution including all these ideas was accepted by Congress.

There was considerable support for a proposal that more must be done to promote Antarctic Meteorology including the work of the International Antarctic Analysis Centre (IAAC). The IAAC is making analyses and prognoses as far north as 30°S and can therefore be considered as a Southern Hemisphere Analysis Centre. It was agreed that the IAAC was an important activity and that WMO should find means of ensuring its successful operation.

An Australian proposal to create a Standing Committee for Antarctica was agreed—its members to be representatives of Members of WMO which are

contracting parties to the Antarctic Treaty. Agreement of the Antarctic Treaty States meeting in consultative assembly is to be obtained to this proposal before it is implemented by WMO.

There was protracted discussion on the question of units to be used for reporting wind speed in meteorological messages for international exchanges. Most delegates favoured the use of m/sec but others, including the U.K. delegation and International Civil Aviation Organization (ICAO) and Intergovernmental Maritime Consultative Organization (IMCO) representatives pointed out that such use would lead to undesirable difficulties and might contribute to accidents. Congress decided that the introduction of m/sec be postponed pending further consideration of the subject with ICAO and IMCO and that, in the meantime, the existing practice of using knots in coded messages will be continued.

Administrative and financial questions.—The time of the Administrative and Finance Committee was mostly devoted to two items, Maximum Expenditure for the Fourth Financial Period and Technical Co-operation. Much of the discussion was centred on two points, whether WMO should have a Technical Assistance Programme of its own and the Operational and Technical Development Fund, both being closely associated with the need to develop National Meteorological Services and world-wide networks and communications. It was decided to establish a fund for development purposes not provided for under Expanded Programme of Technical Assistance and the Special Fund (UN sources) and an amount of 1.5 million U.S. dollars was agreed on the understanding that a plan for the use of the fund, including procedures for its management and operation should first be worked out by the Executive Committee and the Secretary-General and then submitted to Members for their approval.

It was necessary to increase the size of the Secretariat considerably. Sections for Research and for Training were provided for in the Technical Division and the Telecommunications and Networks Section was expanded. A new post of Assistant Secretary-General was made with the duties of supervising and coordinating the work of the Technical and Technical Co-operation Divisions. Reference has already been made to the setting up of a Planning Unit in the Secretariat (see under Technical Questions)—this unit will be responsible directly to the Secretary-General.

The maximum expenditure approved by Congress for the ordinary budget of the Organization for the Fourth Financial Period was $5,373,581, a sum which is nearly twice that approved for the years 1960–63. The conclusion is that the Members decided that in order to make progress with necessary developments, especially those arising from activities placed upon the WMO by the UN General Assembly, the means must be provided both in staff and in money.

There was the customary long debate on proportional contributions. Some countries wishes to retain the existing scale but the majority desired a further move towards the UN Scale which places considerably increased contributions on the U.S.A. and the U.S.S.R. Ultimately it was decided to adopt a scale which is a mean of the existing scale and the 1962–64 UN scale. This

increases the U.K. contribution from 67 units to 68 units and that of the U.S.A. from 215 to 274 units. The U.K. contribution is about 6 per cent of the total and is the third largest.

Congress decided that funds should be provided, from the International Meteorological Organization (IMO) Fund and the General Fund, to finance a lecture to be known as the IMO lecture. This lecture would be delivered by an acknowledged expert at each Congress and would take the form of a review of progress in a branch of meteorology or an account of some new advance in the science. The text of the study would be published by the Organization and the actual lecture would be a shortened version of the text.

Congress confirmed the recommendation of the Executive Committee that it was desirable for the Presidents of Technical Commissions to attend sessions of Congress. It was further considered that when these Presidents were not included in their national delegations to Congress, then their travel and subsistence expenses should be paid by the Organization.

Elections.—There were two candidates for the Presidency, Dr. A. Nyberg of Sweden and Mr. M. F. Taha of the United Arab Republic. Dr. Nyberg was elected by 52 votes to 37. Dr. E. K. Fedorov and Mr. Luiz de Azcárraga were nominated for the posts of First and Second Vice-President. Mr. Luiz de Azcárraga was elected First Vice-President.

The outgoing President, M. André Viaut (France) was voted by acclamation to the first electoral seat on the Executive Committee, and Dr. F. W. Reichelderfer (U.S.A.) was similarly appointed to the second seat. There were 20 candidates for the remaining 10 seats. Out of 88 votes cast in the first ballot the Director-General obtained 54—the next highest number of votes received by any one candidate was 6. The following were elected to the remaining 9 seats: F. A. A. Acquaah (Ghana); N. A. Akingbehin (Nigeria); M. Ayadi (Tunisia); G. Bell (Federal Republic of Germany); A. Garcia (Ecuador); W. J. Gibbs (Australia); P. R. Krishna Rao (India); J. Van Mieghem (Belgium); and M. F. Taha (United Arab Republic).

Appointment of the Secretary-General.—The Executive Committee in Resolution 47 (EC–XIV) expressed complete confidence in Mr. D. A. Davies and recommended to Fourth Congress that he be re-appointed for a further period of four years. There was no other candidate and Mr. Davies was reappointed amidst considerable enthusiasm from the Congress.

The Palais des Nations, Geneva, is as one would expect, ideal for large international gatherings. Apart from the spaciousness and magnificence of the Assembly Hall which is superbly furnished, and the high standard of comfort in the committee rooms, delegates have easy access to post and telegraph, and banking facilities in addition to a restaurant, cafeteria, and several coffee bars. Provision was made for distribution of documents in the conference section where an enquiry desk and travel bureau were also available. As usual, the organization was excellent and the Secretary-General and his staff, both permanent and temporary, are to be congratulated. The translators, typists and duplicating staff in particular deserve special mention as the Congress considered no less than 192 documents, excluding working papers of the three Committees.

NOTES AND NEWS

Seminars on high-level forecasting

A further seminar on forecasting for turbine-powered aircraft operations was held in Bangkok from 20 November to 7 December 1962 under the joint auspices of the World Meteorological Organization (WMO) and the International Civil Aviation Organization (ICAO). Rear Admiral S. Vesa-Rajananda, Director-General of the Thai Meteorological Department, presided. The seminar was similar in its general scope to those previously held in Cairo and Nicosia in 1961.[1] Work in Bangkok was concerned with analysis and forecasting for high-level air routes over tropical and subtropical areas from 65°E to 135°E and 25°N to 15°S.

Over the greater, oceanic, part of this region data are pitifully few, and very little is known, climatology apart, of the true character of the weather systems which occur; and as far as the upper wind and pressure fields are concerned, even the climatology leaves something to be desired. With good reason then, Professor N. E. Laseur of Florida State University, who directed the seminar, warned participants at the outset not to expect cut and dried solutions to be offered to their problems. The programme of work consisted of analysis and forecasting for two selected synoptic situations, each extending over a few days, map discussions, lectures and exercises. The lectures, given by Professor Laseur and chief analysts D. V. Rao, Senior Meteorological Officer, Calcutta, and D. H. Johnson, Climatological Research Division, Bracknell, covered many topics of general interest in aviation forecasting and of specific local interest. Analysis and forecasting techniques successfully used in other parts of the tropics were discussed and there were specific exercises on isogon, streamline and isotach analysis, low-latitude contour analysis, thunderstorm forecasting, differential analysis, and the derivation of prediction equations for statistical forecasting of upper winds. In addition, several of the participants gave talks on their local forecasting problems. These included for example: the description of an objective method of forecasting fog at Mingaladon, by U Thu Ta (Burma); and an account of the squall phenomena, misnamed 'Sumatras', which form in the Malacca Straits and travel eastwards, by W. H. Smith (Meteorological Office, Changi).

The seminar was held in pleasant surroundings at the Headquarters of the Thai Meteorological Department, and the participants, who came from countries ranging from Iran to the Philippines, and from Korea to Australia, were indebted to the Thai Director-General and his staff for affording every facility and courtesy. The problems met in organizing seminars of this kind might be said to vary inversely with the Coriolis parameter, and the hard work put in on this occasion by the co-Directors, Dr. H. Voss (ICAO) and Mr. N. L. Veranneman (WMO), was well appreciated by all concerned.

D. H. J.

REFERENCE

1. Meteorological Office; Seminars in high-level forecasting. *Met. Mag., London*, **91**, 1962, p. 171.

METEOROLOGICAL OFFICE DISCUSSION

Recent advances in seismology

The last Meteorological Office discussion of the winter season was held at the Royal Society of Arts on 18 March 1963.

Dr. H. M. Iyer opened the discussion with a talk centred around a brief summary of the main problems in earthquake seismology, the modern seismological instrumentation, microseisms, and some recent work on digital analysis of seismograms.

Earthquake seismology is concerned with the collection of data from past earthquakes and using the information for the study of the source, magnitude and mechanism of fresh earthquakes. The identification of multiple pulses from an earthquake enables the study of the macroscopic structure of the earth. The seismograph responds to earth movements which are generally converted into analogue electrical signals by some kind of transducer and either recorded photographically by a mirror–galvanometer arrangement or amplified electronically and recorded on strip-chart, magnetic tape or paper tape. Seismographs are now available for a variety of purposes, from working on the deep ocean bottom to operating on the moon's surface.

A very careful study of microseisms using the latest instruments and techniques is slowly unravelling the nature of the waves. It is now fairly well understood how the ocean, coupled with the solid material below, acts as a resonant system and forces like atmospheric turbulence and ocean waves can excite the system. However, extensive study is required to understand fully the relationship between meteorological forces and microseisms. Digital analysis of earthquake surface waves and displaying the change of spectrum with time in the form of energy contours in a frequency–time diagram, promise to give valuable information on the dispersion characteristics of the earthquake surface waves.

The discussion after the talk was mainly regarding the usefulness of microseisms in meteorology.

METEOROLOGICAL OFFICE NEWS

Arts and Crafts exhibition.—The Bracknell Metorological Office Social and Sports Club held its first Arts and Crafts exhibition on 5 May 1963. There were over 200 entries and the quality of the exhibits was very high. The classes covered sewing, embroidery, knitting, cookery, woodwork, rug-making, art, photography and horticulture. Lady Sutton kindly presented the prizes and remarked that she did not realize there was so much talent amongst the staff. It is hoped to make this an annual event.

HONOURS

The following awards were announced in the Birthday Honours List on 8 June 1962:

C.B.E.

Professor P. A. Sheppard, Chairman of the Meteorological Research Committee.

O.B.E.

Dr. R. S. Murgatroyd, B.Sc., A.M.I.E.E., Senior Principal Scientific Officer, Head of the Meteorological Reseach Flight, Farnborough until 4 March 1963.

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